

# Arrangements for detection, interdiction and response to criminal or unauthorized acts involving nuclear and other radioactive materials



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**IAEA**

International Atomic Energy Agency

# Outline

- Introduction
- Arrangements for
  - Prevention
  - Detection
  - Response
- Conclusion

# Security - Generally Speaking

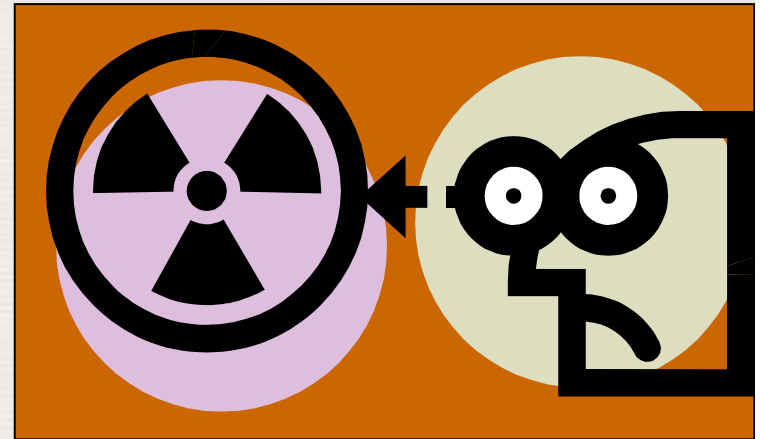
## Measures to prevent, detect, interdict & respond

- Any illicit action or activity with intention to cause harm to persons, damage to property or an adverse impact upon the environment

# Nuclear Security

(as part of General Security)

- The prevention and detection of and response to,
  - theft
  - sabotage
  - unauthorized access
  - illegal transfer or
  - other malicious acts involving nuclear material, other radioactive substances or their associated facilities



# Acts with Radioactive Material

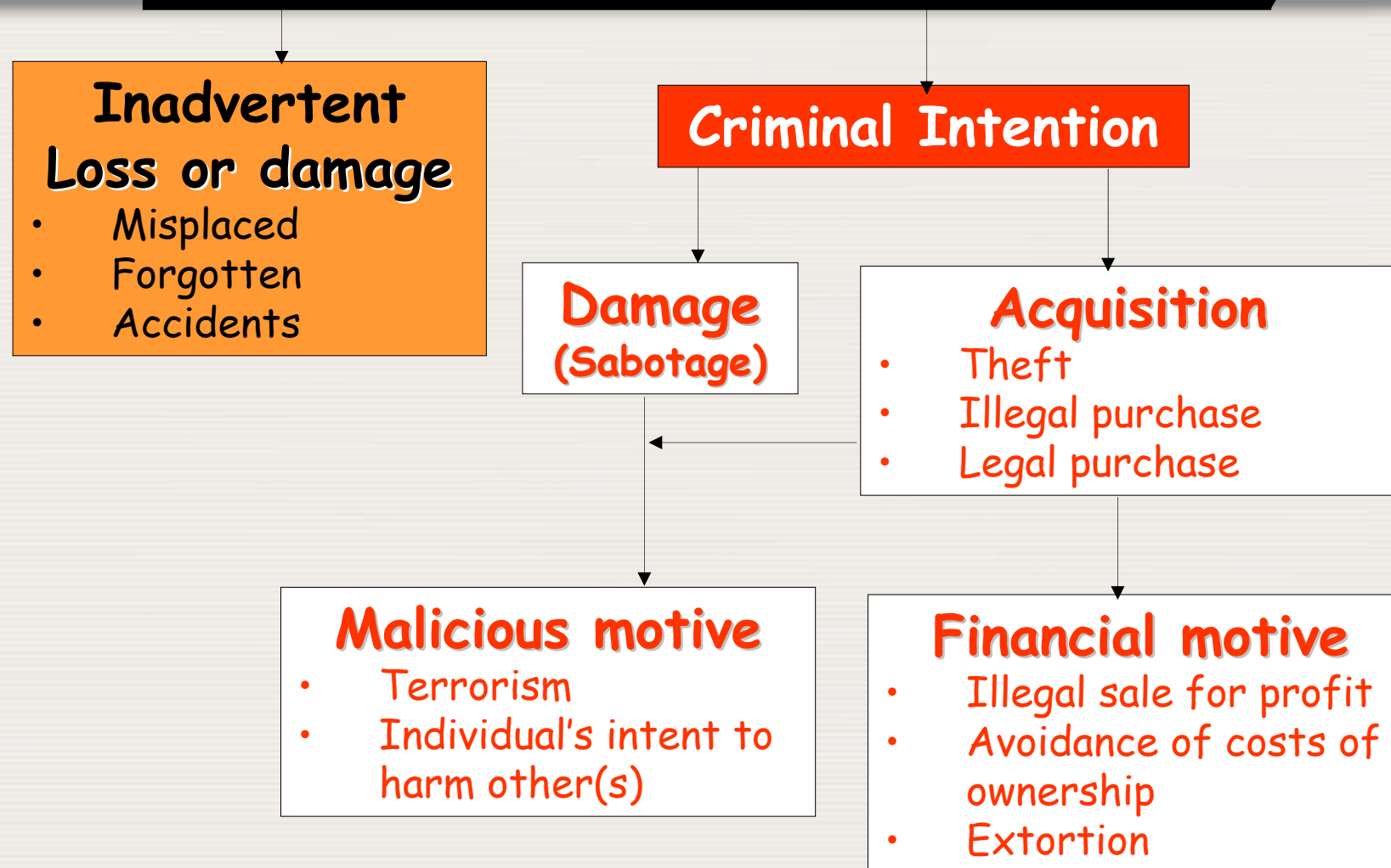
## Authorised Acts

- Import/Export
- Manufacture
- Sell/Transfer
- Possess
- Transport
- Use/Store
- Dispose

## Unauthorised Acts

- Anything that is not authorised  
(other than with exempt material/quantities)

# Unauthorized use of nuclear and other radioactive materials



# Malicious acts involving radioactive materials

- Abandoned suspicious package found
- Bomb threat
- Suspicious luggage/package in an airport or bus station
- Homicide/Suicide bomber
- RDD – dirty bomb
- Disused and/or abandoned source
- Car bomb with driver inside
- Suspicious object inside a vehicle without driver
- Sabotage
  - At nuclear facilities
  - During transport of radioactive materials
  - At facilities where radioactive sources are present
- Illicit trafficking
- Domestic theft

# Criminal act using radioactive material!

**Who? Why? Where?**

**Who?**

- Terrorist, amateur, unstable person, etc

**Why?**

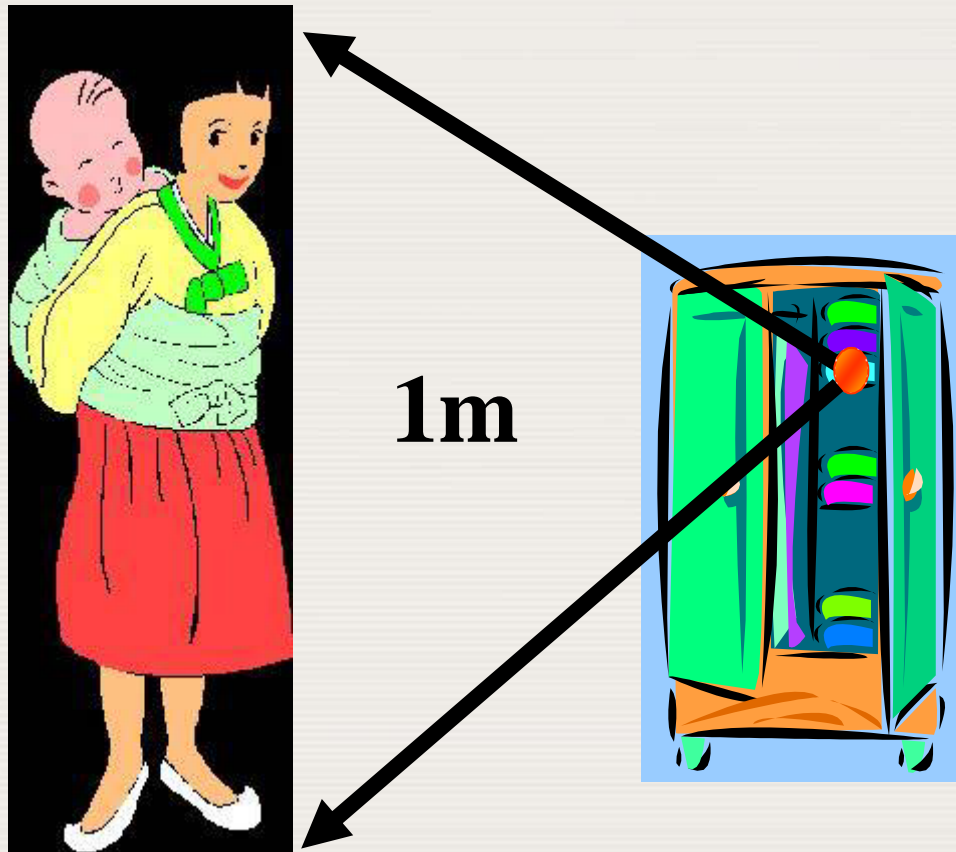
- Political, religious, ideological motive, etc

**Where?**

- Critical facilities & infrastructure, high profile events, symbolic monument or building, enclosed spaces, radioactive materials in transit, etc

# Potential consequences I

## Overexposure of persons



- Near by for few weeks
- Deaths may occur in less than 1 month

# Potential consequences II

## Dispersal of radioactive materials

### Non violent mode

- Aircraft, ventilation system, spray or manually

### Violent mode

- Explosive/dirty bomb

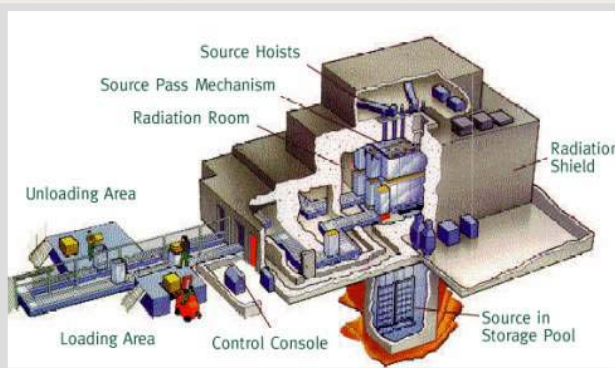
**Catastrophic damages (in case of nuclear yield)**

# Intense media/public interest

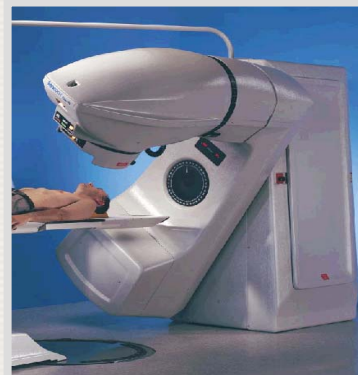


# Is there a risk? (1)

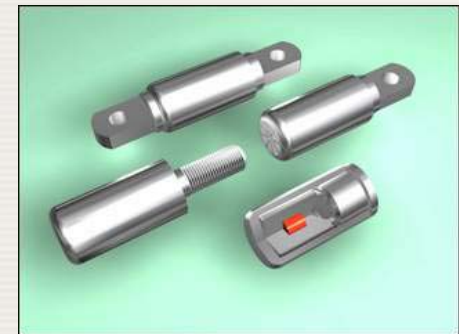
- **Availability**
  - Radioactive sources are abundant and widespread all around the world!
  - Thousands of powerful radioactive sources suitable for criminal are used in industrial, medical and research applications



**Food irradiator**  
**~10,000,000 Ci**  
 **$^{60}\text{Co}$**



**Teletherapy unit**  
**(~13,000 Ci  $^{60}\text{Co}$ )**



**Sealed gamma**  
**sources**

# Suitable radioactive materials for criminal use

- Industrial & medical sources

- Americium
- Cesium
- Cobalt
- Europium
- Iridium
- Radium
- Polonium
- Strontium
- Technetium

- Nuclear materials

- Uranium
- Plutonium

**PERIODIC TABLE**  
**Atomic Properties of the Elements**

**NIST**  
National Institute of Standards and Technology  
Technology Administration, U.S. Department of Commerce

**Frequently used fundamental physical constants**  
For the most accurate values of these and other constants, visit [physics.nist.gov/constants](http://physics.nist.gov/constants)  
1 second = 9 192 631 770 periods of radiation corresponding to the transition between the two hyperfine levels of the ground state of  $^{133}\text{Cs}$

speed of light in vacuum  $c = 299\,792\,458\text{ m s}^{-1}$  (exact)  
Planck constant  $h = 6.626\,069\,57 \times 10^{-34}\text{ J s}$  (exact)  
elementary charge  $e = 1.602\,176\,634 \times 10^{-19}\text{ C}$   
electron mass  $m_e = 9.109\,383\,56 \times 10^{-31}\text{ kg}$   
proton mass  $m_p = 1.672\,621\,627 \times 10^{-27}\text{ kg}$   
fine-structure constant  $\alpha = 1/137.035\,999\,074$   
Rydberg constant  $R_\infty = 10\,973\,731.762\text{ m}^{-1}$   
 $R_\infty c = 3.289\,842 \times 10^{15}\text{ Hz}$   
 $R_\infty h = 13.605\,698\text{ eV}$   
Boltzmann constant  $k = 1.380\,650\,4 \times 10^{-23}\text{ J K}^{-1}$

Legend:   
 Solids  
 Liquids  
 Gases  
 Artificially Prepared

<p>Group 1 IA</p> <p>1 H Hydrogen 1.00794</p> <p>2 He Helium 4.002602</p>																	
<p>Group 2 IIA</p> <p>3 Li Lithium 6.941</p> <p>4 Be Beryllium 9.012182</p> <p>5 B Boron 10.811</p> <p>6 C Carbon 12.011</p> <p>7 N Nitrogen 14.00643</p> <p>8 O Oxygen 15.9994</p> <p>9 F Fluorine 18.9984032</p> <p>10 Ne Neon 20.1797</p>																	
<p>Group 11 IB</p> <p>11 Na Sodium 22.98976928</p> <p>12 Mg Magnesium 24.304</p> <p>13 Al Aluminum 26.9815386</p> <p>14 Si Silicon 28.0855</p> <p>15 P Phosphorus 30.973762</p> <p>16 S Sulfur 32.06</p> <p>17 Cl Chlorine 35.453</p> <p>18 Ar Argon 39.948</p>																	
<p>Group 12 IIB</p> <p>19 K Potassium 39.0983</p> <p>20 Ca Calcium 40.078</p> <p>21 Sc Scandium 44.955912</p> <p>22 Ti Titanium 47.867</p> <p>23 V Vanadium 50.9415</p> <p>24 Cr Chromium 51.9961</p> <p>25 Mn Manganese 54.938045</p> <p>26 Fe Iron 55.845</p> <p>27 Co Cobalt 58.933195</p> <p>28 Ni Nickel 58.6934</p> <p>29 Cu Copper 63.546</p> <p>30 Zn Zinc 65.38</p> <p>31 Ga Gallium 69.723</p> <p>32 Ge Germanium 72.64</p> <p>33 As Arsenic 74.9216</p> <p>34 Se Selenium 78.96</p> <p>35 Br Bromine 79.904</p> <p>36 Kr Krypton 83.798</p>																	
<p>Group 13 IIIA</p> <p>37 Rb Rubidium 85.4678</p> <p>38 Sr Strontium 87.62</p> <p>39 Y Yttrium 88.90584</p> <p>40 Zr Zirconium 91.224</p> <p>41 Nb Niobium 92.90638</p> <p>42 Mo Molybdenum 95.94</p> <p>43 Tc Technetium 98.906251</p> <p>44 Ru Ruthenium 101.07</p> <p>45 Rh Rhodium 102.90550</p> <p>46 Pd Palladium 106.42</p> <p>47 Ag Silver 107.8682</p> <p>48 Cd Cadmium 112.411</p> <p>49 In Indium 114.818</p> <p>50 Sn Tin 118.710</p> <p>51 Sb Bismuth 121.757</p> <p>52 Te Tellurium 127.60</p> <p>53 I Iodine 126.90447</p> <p>54 Xe Xenon 131.29</p>																	
<p>Group 14 IVA</p> <p>55 Cs Cesium 132.90545196</p> <p>56 Ba Barium 137.327</p> <p>57 La Lanthanum 138.90547</p> <p>58 Ce Cerium 140.116</p> <p>59 Pr Praseodymium 140.90768</p> <p>60 Nd Neodymium 144.24</p> <p>61 Pm Promethium 144.9127</p> <p>62 Sm Samarium 150.36</p> <p>63 Eu Europium 151.964</p> <p>64 Gd Gadolinium 157.25</p> <p>65 Tb Terbium 158.92534</p> <p>66 Dy Dysprosium 162.500</p> <p>67 Ho Holmium 164.93032</p> <p>68 Er Erbium 167.259</p> <p>69 Tm Thulium 168.930421</p> <p>70 Yb Ytterbium 173.04</p> <p>71 Lu Lutetium 174.967</p>																	
<p>Group 15 VA</p> <p>87 Fr Francium 223.0197262</p> <p>88 Ra Radium 226.0254</p> <p>89 Ac Actinium 227.027755</p> <p>90 Th Thorium 232.0377</p> <p>91 Pa Protactinium 231.036889</p> <p>92 U Uranium 238.02891</p> <p>93 Np Neptunium 237.048173</p> <p>94 Pu Plutonium 244.06422</p> <p>95 Am Americium 243.061381</p> <p>96 Cm Curium 247.070351</p> <p>97 Bk Berkelium 247.070351</p> <p>98 Cf Californium 251.0833</p> <p>99 Es Einsteinium 252.0833</p> <p>100 Fm Fermium 257.10528</p> <p>101 Md Mendelevium 258.10528</p> <p>102 No Nobelium 259.10528</p> <p>103 Lr Lawrencium 262.10528</p>																	
<p>Group 16 VIA</p> <p>104 Rf Rutherfordium 261.10528</p> <p>105 Db Dubnium 262.10528</p> <p>106 Sg Seaborgium 266.10528</p> <p>107 Bh Bohrium 264.10528</p> <p>108 Hs Hassium 277.10528</p> <p>109 Mt Meitnerium 268.10528</p> <p>110 Uun Ununium 271.10528</p> <p>111 Uuu Ununium 272.10528</p> <p>112 Uub Ununium 285.10528</p> <p>113 Uuh Ununium 289.10528</p> <p>114 Uuq Ununium 289.10528</p> <p>115 Uuq Ununium 289.10528</p> <p>116 Uuh Ununium 289.10528</p> <p>117 Uuh Ununium 289.10528</p> <p>118 Uuh Ununium 289.10528</p> <p>119 Uuh Ununium 289.10528</p> <p>120 Uuh Ununium 289.10528</p>																	
<p>Group 17 VIIA</p> <p>121 Uue Ununium 289.10528</p> <p>122 Uuq Ununium 289.10528</p> <p>123 Uuq Ununium 289.10528</p> <p>124 Uuq Ununium 289.10528</p> <p>125 Uuq Ununium 289.10528</p> <p>126 Uuq Ununium 289.10528</p> <p>127 Uuq Ununium 289.10528</p> <p>128 Uuq Ununium 289.10528</p> <p>129 Uuq Ununium 289.10528</p> <p>130 Uuq Ununium 289.10528</p>																	
<p>Group 18 VIIIA</p> <p>131 Uuo Ununium 289.10528</p> <p>132 Uuq Ununium 289.10528</p> <p>133 Uuq Ununium 289.10528</p> <p>134 Uuq Ununium 289.10528</p> <p>135 Uuq Ununium 289.10528</p> <p>136 Uuq Ununium 289.10528</p> <p>137 Uuq Ununium 289.10528</p> <p>138 Uuq Ununium 289.10528</p> <p>139 Uuq Ununium 289.10528</p> <p>140 Uuq Ununium 289.10528</p>																	

Based upon  $^{12}\text{C}$ . ( ) indicates the mass number of the most stable isotope.

For a description of the data, visit [physics.nist.gov/data](http://physics.nist.gov/data)

NIST SP 966 (September 2003)

# Some current application of these radioactive materials

- **Cesium-137**

- food irradiation
- wide variety of industrial instruments
- diagnosis and treatment
- sterilisation of medical equipment

- **Cobalt-60**

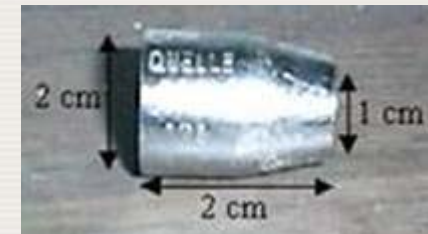
- cancer radiotherapy
- non-destructive testing of welds and castings
- large variety of measurement and test instruments
- food irradiation

- **Strontium-90**

- tracer in medical and agricultural studies
- power source in specialist long-life, light-weight power supplies
- electron tubes
- treatment of eye diseases and bone cancer

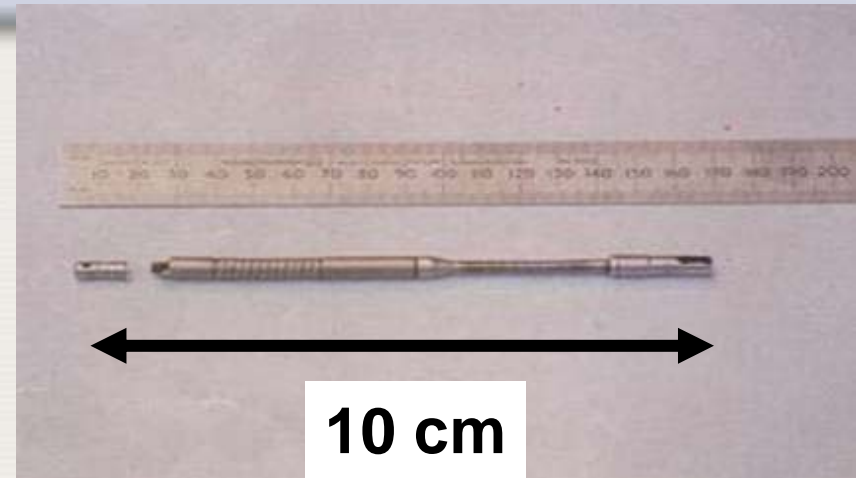
- **Iridium-192**

- non-destructive testing, especially in the oil and airline industries
- cancer therapy



# Source Materials

## Example - Radiography Sources



Contain 3 to 150 Ci of  
 $^{60}\text{Co}$  or  $^{192}\text{Ir}$  or  $^{137}\text{Cs}$

# Is there a risk? (2)

- **Vulnerabilities**

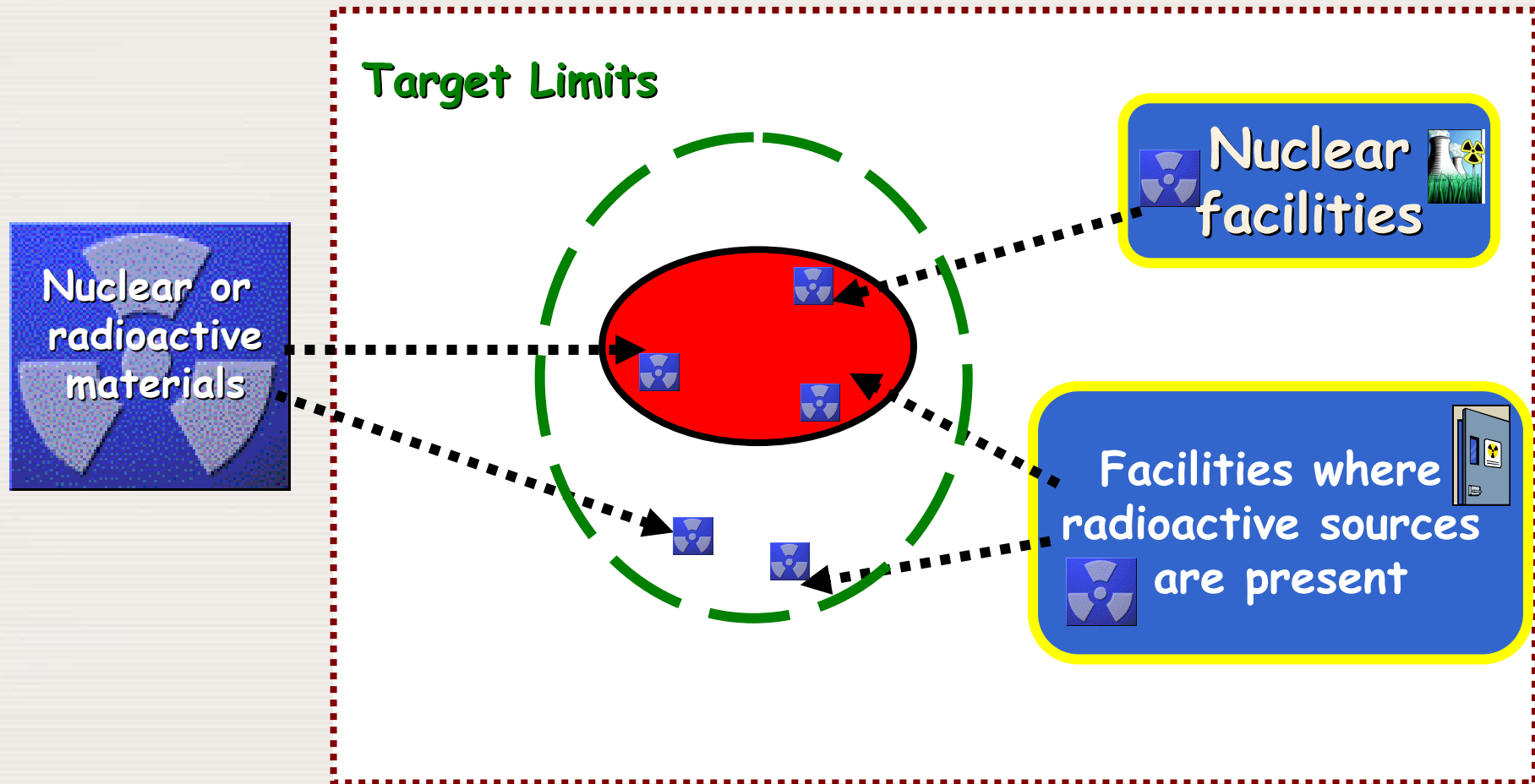
- A large number of lost or stolen radioactive sources which have not been recovered
- Radioactive sources at facilities of origin without adequate protection
  - potential for more thefts
- Sufficient materials for a dirty bomb could be obtained relatively easily by terrorists through theft and fraud

- **Motivation**

- Reports showing intention to acquire and/or use radioactive materials for malicious purposes

# Country Situation

## State Borders



# Prevention

- **Physical protection of nuclear & other radioactive material at their associated facilities and during transport**
  - An essential element in the first line of defence against criminal offences
  - Vital in preventing material from becoming out of regulatory control
- **Lockdown of strategic locations such as critical facilities & infrastructure, venues, etc**
  - Radiological search/survey at strategic locations to verify whether or not radioactive material is present prior its use
- **Deterrence**
- **Information security**
- **Trustworthiness**

# Detection

## Via Instruments

- Devices that are portable or placed at fixed locations and operated as part of normal commerce such as:

- Radiation Portal Monitors (RPMs)



- Personal Radiation Detectors (PRDs)



- Hand-held Radionuclide Identification Device (RID)



- Neutron Search Device (NSD)



- Special Detectors



# Detection

## Via Information Alerts

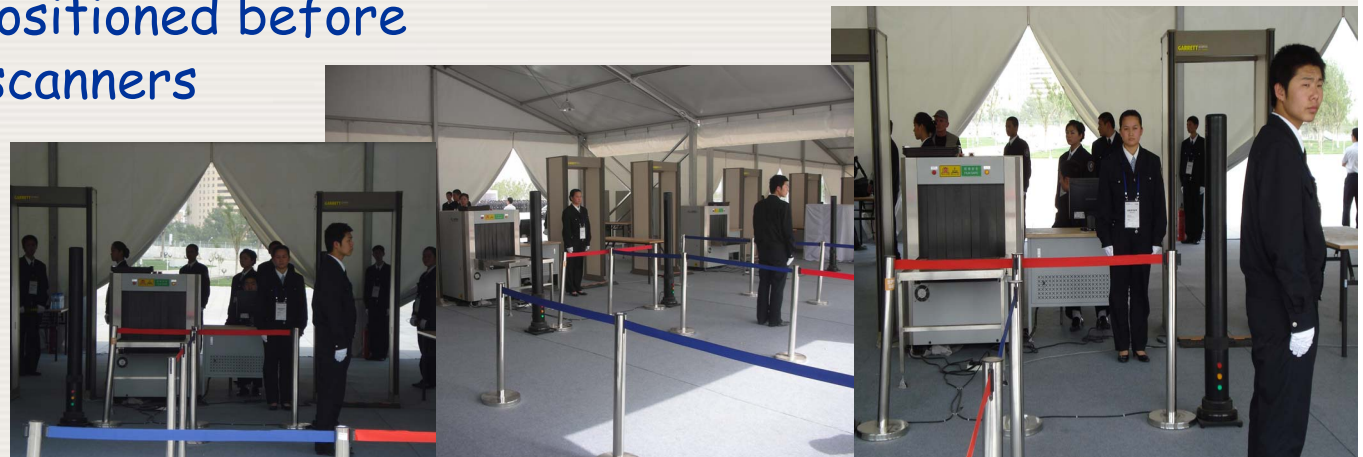
- Variety of sources, including
  - Intelligence
  - Medical symptoms
  - Accounting & shipper/receiver discrepancies
  - Border inspections

# Radiation detection by instruments

- Radiological surveys at strategic locations
  - To detect presence of radioactive materials
  - To interdict illicit radioactive material from entering in a strategic location

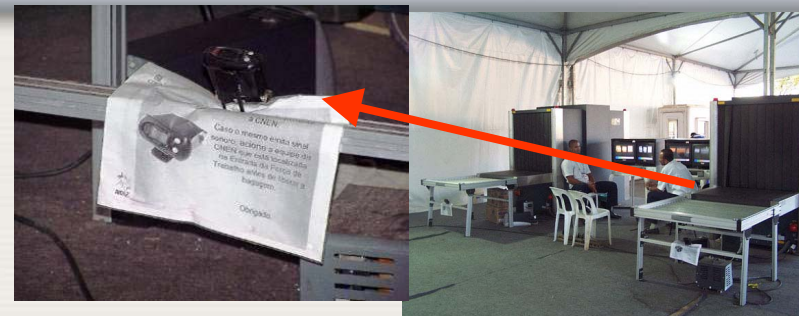
# Example (1) - Screening of persons

- Officers carrying PRD, positioned in each checkpoint line, after metal detectors & scanners
- Officers carrying BACKPACK
  - Covert searching
- Radiation monitor positioned before metal detectors & scanners



## Example (2) - Screening of handbags & cargo

- PRD clipped under tray of X-Ray scanner
- Radiation portal monitor positioned at cargo vehicle entrance



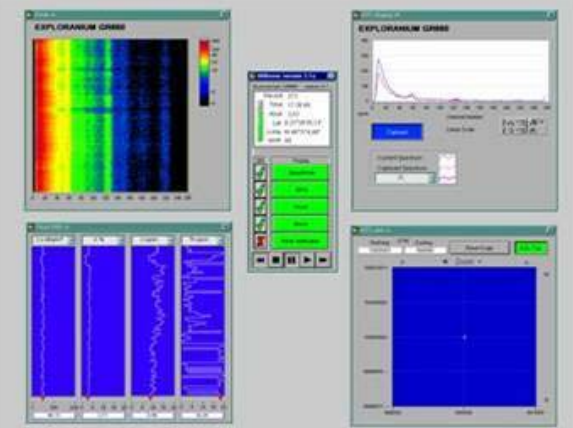
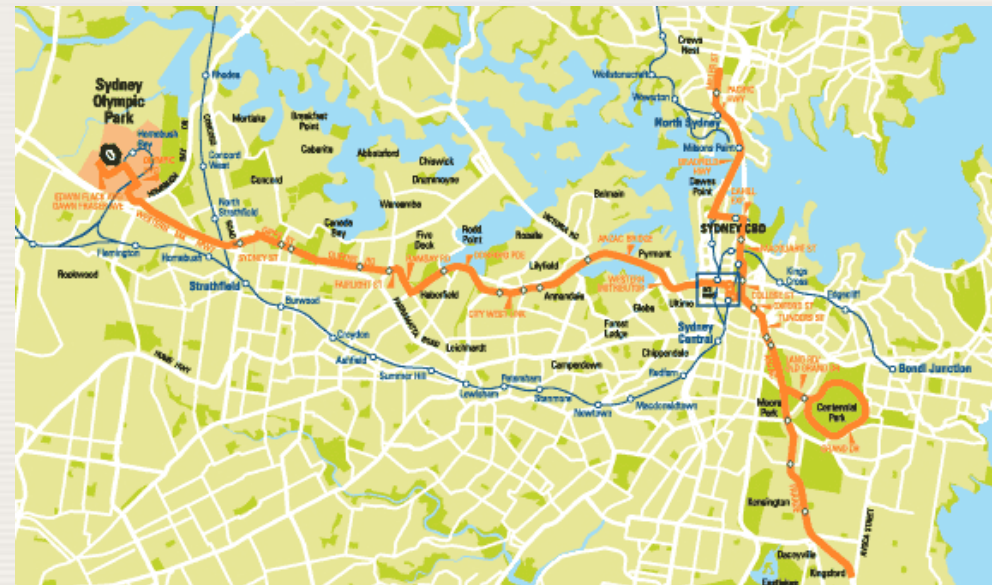
## Example (3) - Survey of Open Areas Events

- Security officers carrying PRD & BACKPACK during Marathon & Triathlon



# Example (4) - Survey of Open Areas Events Combined use

- Use of BACKPACKS and CAR/AIR BORNE SYSTEMS



# Radiation detection by information gathering

- Operational information
  - Gathering and analysing information aiming to identify suspicious activities or abnormalities that may indicate criminal or unauthorized acts involving radioactive material within the State such as:
    - Activities of non-State actors that could pose a risk to nuclear security
    - Illicit and unauthorized operations both within the State & across borders
    - Open-source
    - Ad-hoc reporting based on on-going observation or conventional routine inspections by law enforcement
- Medical surveillance
  - Appearance of medical signs & symptoms related to radiation injuries
- Regulatory non-compliance including loss of control through theft

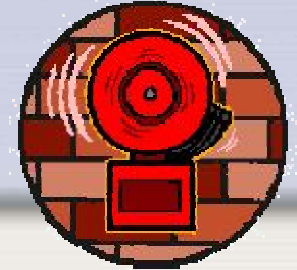
# Response

- **Assessment phase**
  - Initiated by an alarm or alert
  - If confirmed, nuclear security event
- **Management phase**
  - Establishment & management of crime scene
  - Subsequent criminal investigation, prosecution or extradition of offenders
  - Place material under regulatory control

# Assessment of instrument alarms

**What to do if an alarm is triggered?**

# Basic steps



- Secure the individual or material
- Verify the alarm
  - Is this a real alarm or a false alarm?
    - Secondary inspection
- Measure the level of radiation
  - If below limits
    - identify and classify the radioactive material
    - assess if it is an innocent or non-innocent alarm
  - Level of radiation above limits?
    - Yes, Tertiary inspection
- Implement countermeasures

# Is this a real alarm or a false alarm?

- **Action**
  - Verification of alarm - Secondary Inspection
    - False alarm
    - Real alarm
      - Innocent
      - Confirmed non-innocent alarm

# False Alarms

**Can be activated by instruments and cannot be confirmed by independent radiation measurement**

- **False alarms by instruments**
  - Effects of instruments electronic (high probability)
  - Changing background by NORM in buildings, streets (high probability)
  - Mechanical shocks by the user (middle probability)
  - Atmospheric background fluctuation (low probability)
  - Radio frequency interferences (low probability)

# Real alarm

## Innocent or Non-innocent?

- **To confirm**
  - Measure radiation level
  - Identify radioactive element
  - Categorize
    - NORM, medical, industrial or nuclear material

# Innocent alarms (1)

- Radioactive material detected in persons that had medical treatment or examination
  - certificate
- Cargo with naturally occurring radioactive material (NORM)
- Legal shipment of radioactive material
  - adequate transport documentation
  - correct timeframe and transport route

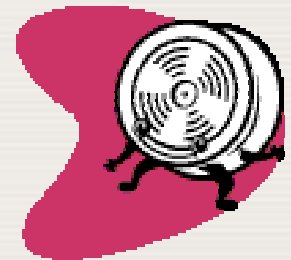
# Innocent alarms (2)

- **Examples of material (NORM)**
  - Green glass containing Uranium
  - Video screens and some camera lenses with Thorium
  - Fertilizers containing K-40
  - Ceramics containing Uranium and Thorium
  - Welding rods containing Thorium
  - Tailings from oil industry or desalination plants containing Radium-226 and Thorium

**Those involved in criminal or terrorist activities can orchestrate innocent alarms to test nuclear security measures**

# Non-innocent alarm (1)

- Everything that is not innocent and radiation level is above threshold



- Take special precautions if
  - ✓ Dose rate  $> 100 \mu\text{Sv.h}^{-1}$  at 1m from object
  - ✓ Presence of neutrons



# Non-innocent alarm (2)

HARMFUL?

Expert support needed?

→ Tertiary Inspection

# Potentially Harmful Situations

## Key Elements

- ✓ **Safety** procedures
- ✓ **Isolation** of suspected material
- ✓ **Notification** process
- ✓ **Crime-scene** management

# Non-innocent alarms (3)

- **Cordon off the area**

- Radiation dose rate at  $100 \mu\text{Sv.h}^{-1}$



- **Seizure and temporary storage of items**

- Safety measures should be applied to adequately store, pack or even remove radioactive material

→ Additional expert support may be needed

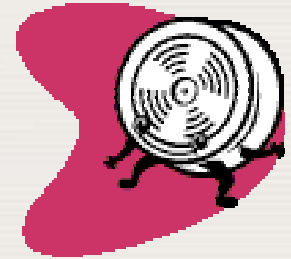
- **Notify appropriate authority**

- Notification procedure
- Ask for help



# Non-innocent alarms (4)

- **Initial investigation**
  - Search for any additional information
  - Preserve the scene
    - If not possible, move item to a safe location
  - Do not forget to control people



# Radiation Hazard

- **Minimizing radiation exposure**
  - Maintain safe distance from radioactive source
  - Limit time in close proximity of source
  - Use shielding materials, if required
- **Do not touch or disturb any materials, which have leaked or spilled from a suspicious item**
- **Do not eat, drink or smoke at the scene**

# Tertiary Inspection and Support Team (1)

## Required if situation escalates

- **Roles and responsibilities**

- Provide support to identify and classify any radioactive material that causes an alarm
- Assess radiological risk and provide advise on radiation safety
- Advise and assist Incident Commander in COUNTERMEASURES
  - Mitigation and isolation of areas
  - Restriction of operations
  - Recovery, transport and storage of radioactive material
  - Sheltering
  - Evacuation

# Tertiary Inspection and Support Team (2)

- **Roles and responsibilities** (continue)
  - Assist operational response and crime-scene management
    - Forensics, HazMat, Anti-bomb squad
  - Perform car/air borne or backpack and other specialized surveys
  - Control of operations involving radioactive material
  - Use of specific codes to assess radiation dose due different exposure pathway
  - Use dispersion codes predictions and/or environmental impact assessment

# Tertiary Inspection and Support Team (3)

- **Challenges**

- Adequate and timely response to a nuclear security event with potential or actual radiological consequences
- Coordination with law enforcement during response
- Information flow
- Team transport during an event

# Assessment of information alerts

- **Basic steps**
  - Evaluation of the quality of the information
  - Identification of the possible location(s) of the material, including a search for radioactive material out of regulatory control
  - Identification of the involved radioactive material

# Summary

Arrangements for detection, interdiction & response,  
including those related to mitigation of consequences

- **Identify security organizations**  
(WHICH) - Leading and Supporting organizations
- **Plan early**  
(WHEN) - As soon as possible
- **Develop a strategy**  
(HOW) - Concept of operations, including response procedures

**Verify performance**

(BY) - Training all responders and conducting and evaluating exercises

# Conclusion

# Areas of concern

- Security of radioactive sources
  - Improvement of their protection, control and accounting is required
- Detection capabilities at land borders and sea ports require attention, however...
- More information is required to assess effectiveness of detection and hence risks posed by cross-border illicit trafficking activities

*...Thank you for your attention*

